

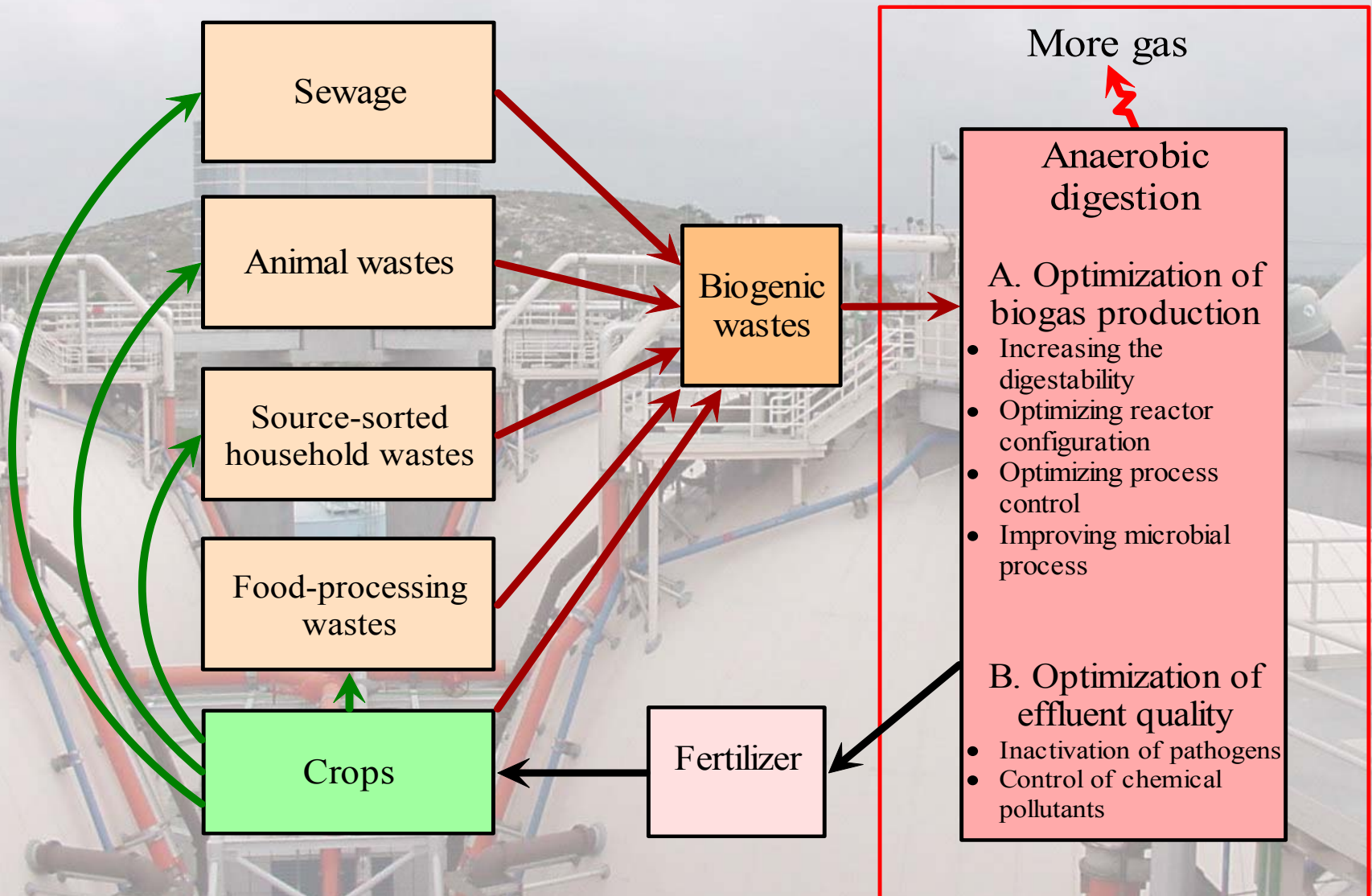
New Directions for Anaerobic Digestion

Dr. Keith D. Thomsen

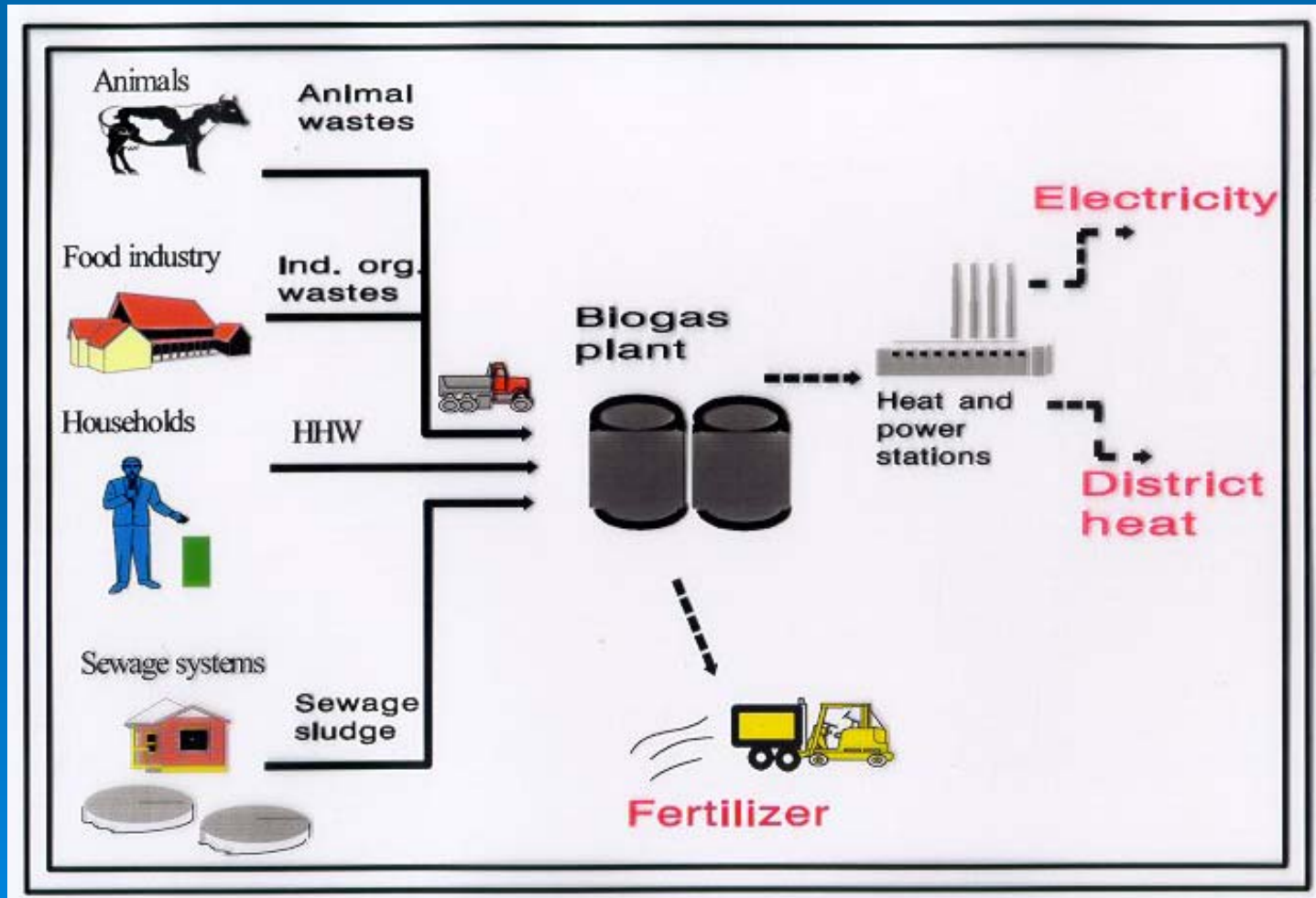


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Main issues for AD today



Codigestion concept

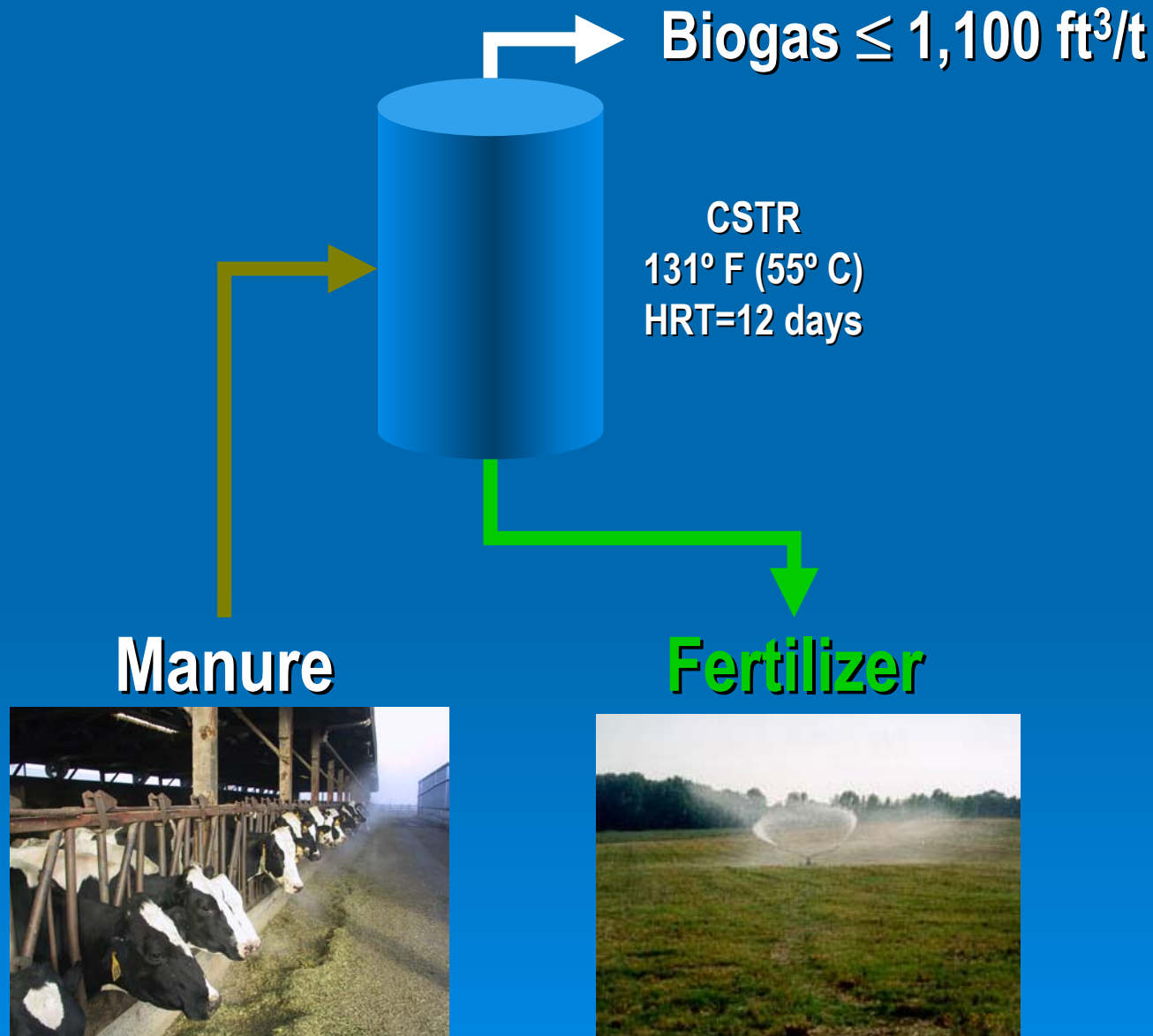


Gas potential of different waste

Type	Organic content	TS (%)	VS (%)	Gas yield m ₃ /ton	Notice
Stomach/intest. content	Carbohydrate, protein, lipids		15-20	50-70	
Flotation sludge	65-70% protein, 30-35% lipid		13-18	90-130	Process adaptation
Bentonite Bound oil	80% lipid, 20% other organic matter		40-45	350-450	Corrosive bentonit Process adaptation
Fish oil	30-50% lipid		80-85	350-600	Process adaptation
Whey	75-80% lactose, 20-25% protein	8-12	7-10	40-55	
Concentrated whey	75-80% lactose, 20-25% protein	20-25	18-22	100-130	
Size water	70% protein, 30% lipid		10-15	70-100	High N-content Process adaptation
Marmelade	90% sugar, fruit organic acids		50	300	
Soya oil/margar.	90% vegetable oil		90	800-1000	Process adaptation
Spiritus	40% alcohol		40	240	
Sludge	Carbohydrate, lipid, protein		3-4	17-22	Sanitation. May contain heavy metals
Conc. sludge	Carbohydrate, lipid, protein		15-20	85-110	Sanitation. May contain heavy metals
Source sorted HHW	Carbohydrate, lipid, protein	25-35	20-30	150-240	Sanitation Plastic, other articles

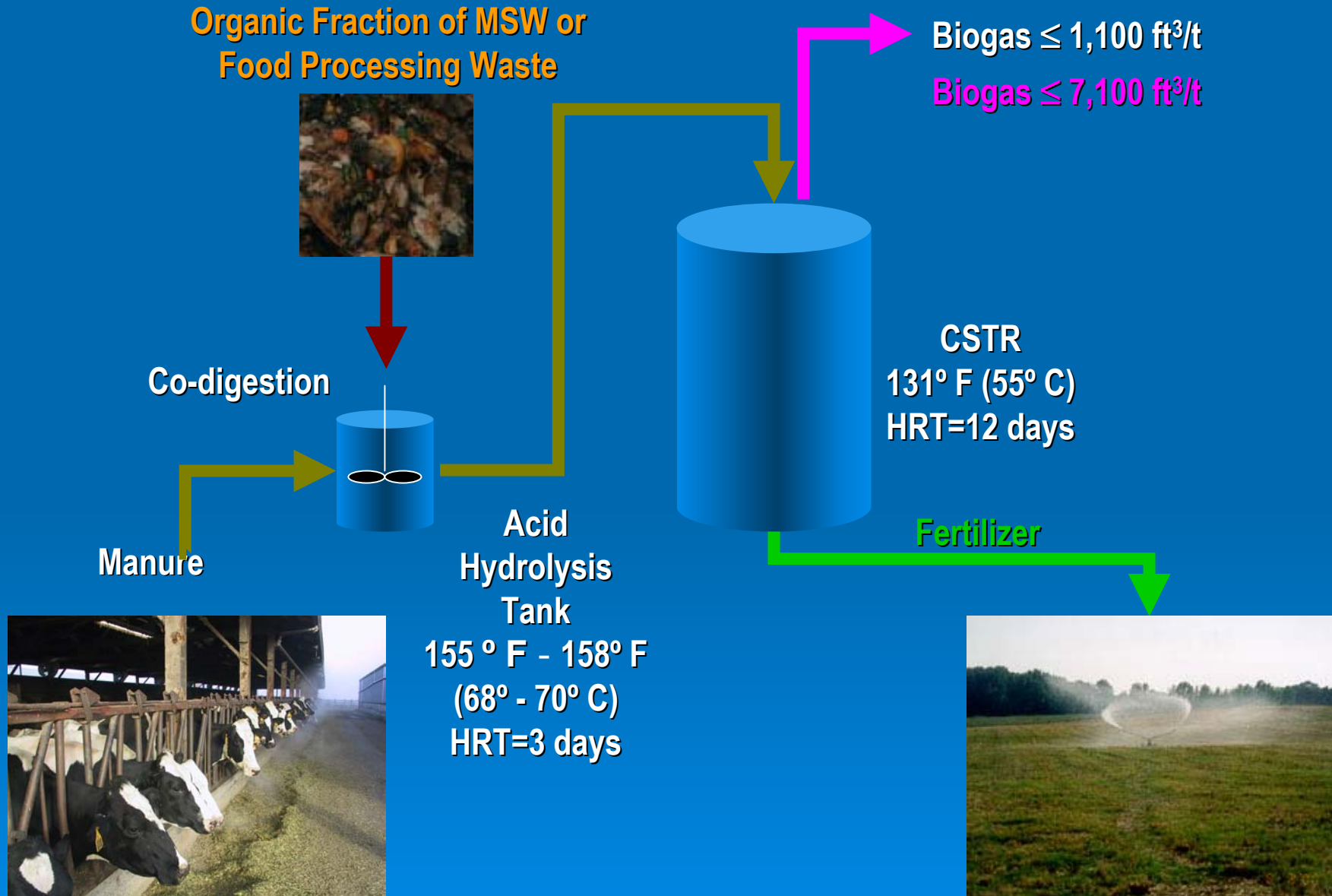
Typical Biogas Plant

(Single Stream Digestion)



Typical Biogas Plant

(Multi-stream Co-digestion)

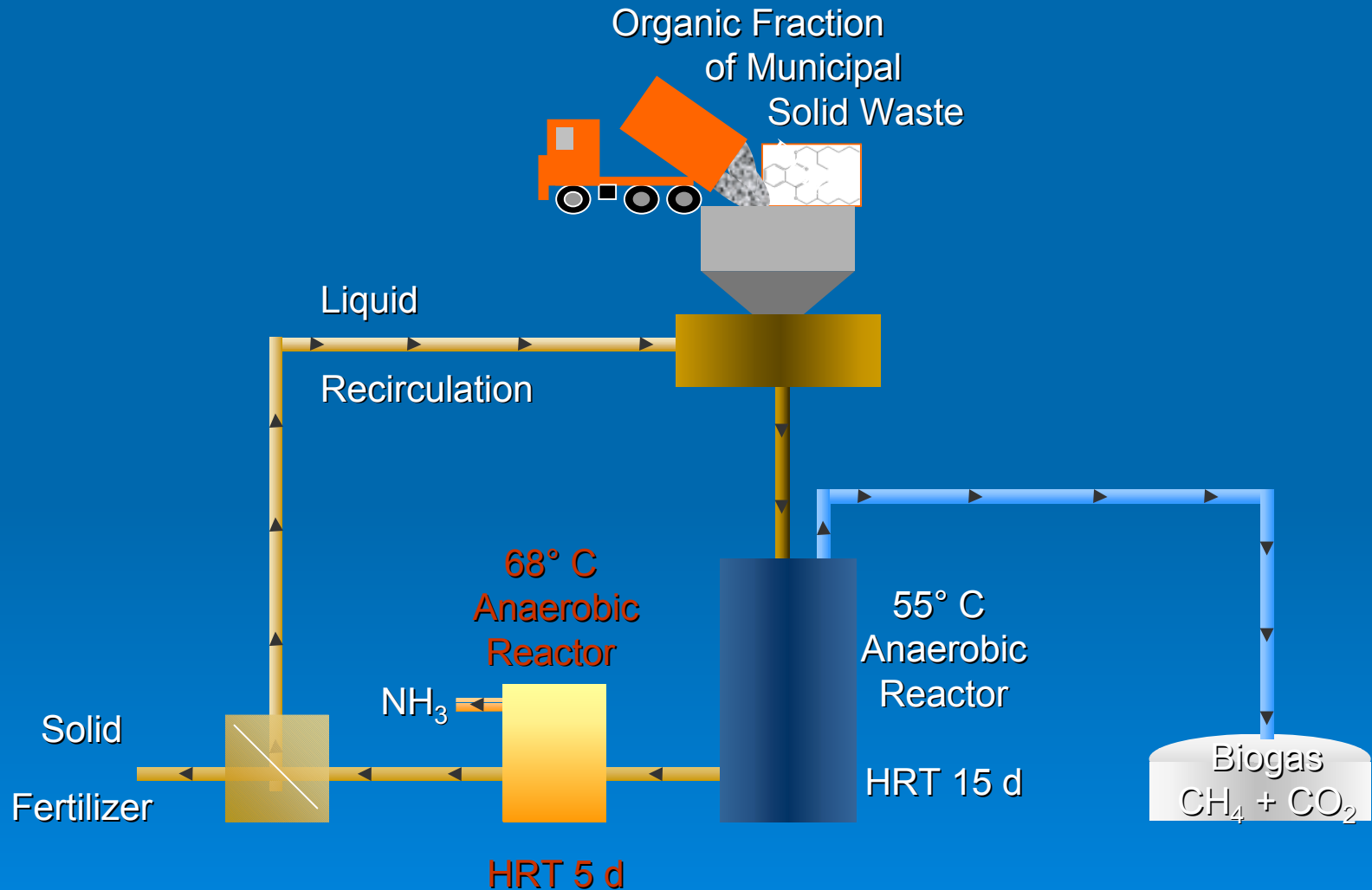


Results: 2-Phase versus 1-Phase Treatment

	Single Phase	Two Phase
	131° F (55° C)	155° F + 131° F (68° C + 55° C)
VS reduction	43% (2%)	47% (1%)
Methane yield	239 (5) ml/(g VS x d)	259 (4) ml/(g VS x d)

Standard deviation in brackets

A New Concept for the Anaerobic Treatment of the Organic Fraction of Municipal Solid Waste



Reasons for Two Phase Anaerobic Digestion System

- 1 Removal of ammonia by means of stripping.
 - ▶ No accumulation of NH_3 in recirculation
- 2 Sanitation of the waste material.
 - ▶ Safe fertilizer product
- 3 Higher conversion of xenobiotics by adapted hyperthermophilic cultures due to higher solubility of hydrophobic pollutants.
 - ▶ Safe fertilizer product
- 4 Enhanced hydrolysis of recalcitrant organic matter
 - ▶ Increased VS reduction
 - ▶ Less sludge production

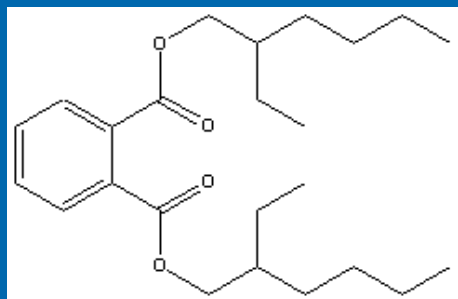
What About Xenobiotics?

- Aerobic Digestion Methods can destroy simple xenobiotic compounds, but not chlorinated & other recalcitrant compounds
- Thermophilic anaerobic digestion destroys recalcitrant xenobiotic compounds more efficiently/effectively than mesophilic anaerobic digestion

Phthalic Acid Esters

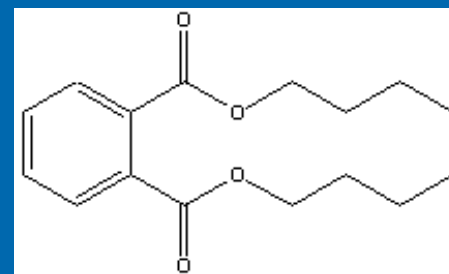
DEHP

(Di-(2-ethylhexyl)phthalate)



DBP

(Dibutylphthalate)



• Water solubility

$0.6 - 2.6 \cdot 10^{-3} \text{ mg/l}$

$K_{OW} = 7.0 - 7.8$

$1.5 - 13 \text{ mg/l}$

$K_{OW} = 3.7 - 5.2$

Effluent as Fertilizer

Threshold values of xenobiotic compounds
in organic waste for the use as fertilizer

Xenobiotic compound		Threshold (mg/kg-TS)
PAH	Polycyclic aromatic hydrocarbons	3
DEHP	Di-(2-ethylhexyl)phthalate	50
NPE	Nonyl phenol + ethoxylates	10
LAS	Linear alkyl benzene sulphonates	1300

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Results: 2-Phase versus 1-Phase Treatment

	Single Phase	Two Phase
	131° F (55° C)	155° F + 131° F (68° C + 55° C)
VS reduction	67% (5%)	83% (2%)
DEHP conversion	No conversion	36% (2%)

Standard deviation in parentheses

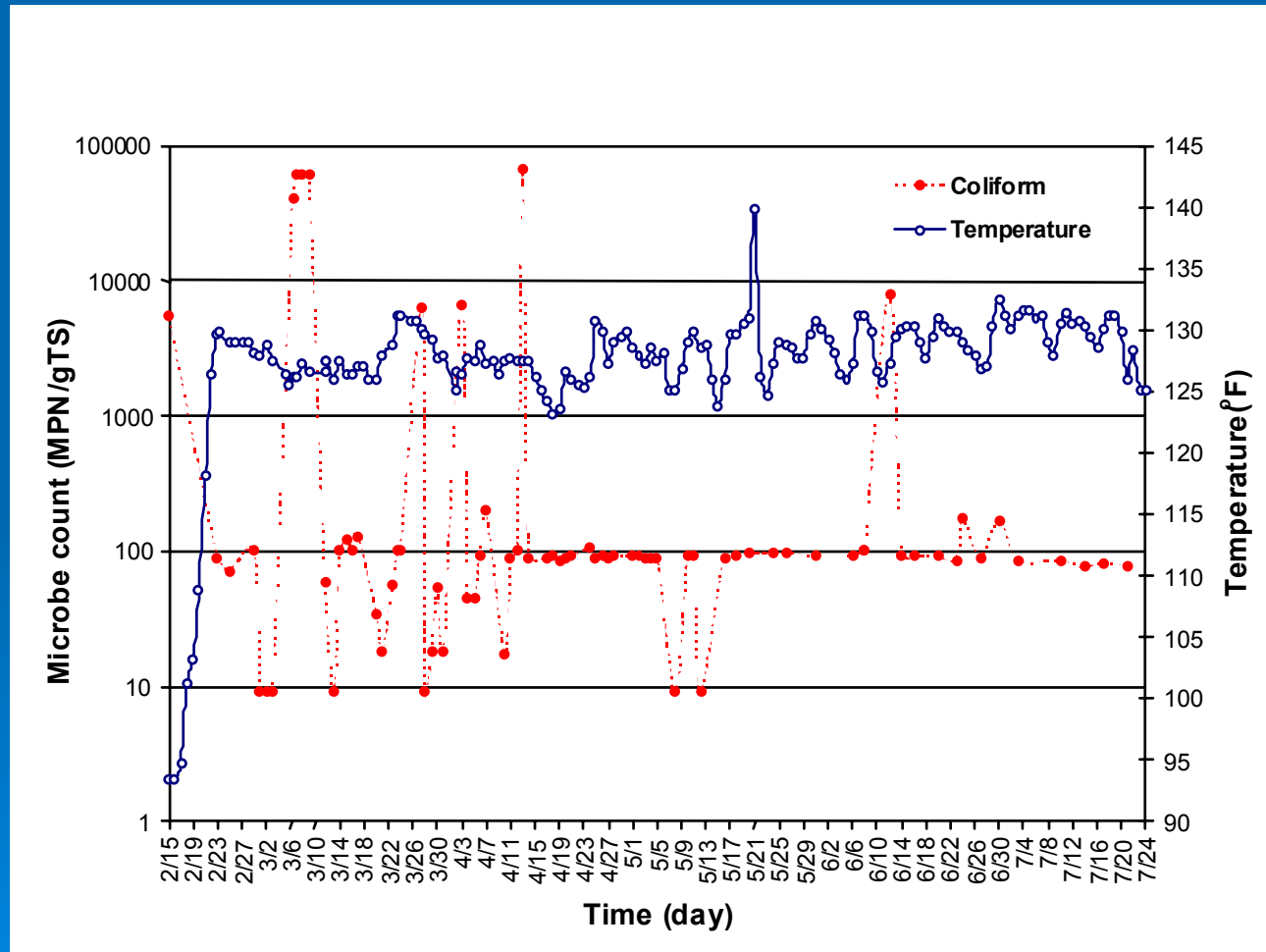
Table US-1. Requirements for Biosolids Classifications

Requirement	USA 40 CFR Part 503, Subsection 503.32			
	Class A Processes and site restrictions	Class A analysis	Class B processes and site restrictions	Class B analysis
general (in addition to specifics of process and analysis alternatives)	no site restrictions	< 1000 MPN/g DS fecal coliform density or <3/4 MPN/g DS <i>Salmonella</i> sp. density	site restriction durations depend on land use	
Alternative 1	time-temperature relation depending on solids percentage			<2,000,000 MPN/g DS fecal coliform density
Alternative 2	pH > 12, duration 72 hours including T > 52oC for >12 hours, drying to > 50% solids		Processes to further reduce pathogens (PFRP)	
Alternative 3		< 1/4 PFU/g DS enteric virus and < 1/4 viable helminth ovum/g DS in sludge either before or after pathogen treatment	equivalent to PSRP	
Alternative 4		< 1/4 PFU/g DS enteric virus and < 1/4 viable helminth ovum/g DS in sludge solids at last point of processor access		
Alternative 5	Processes to further reduce pathogens (PFRP)			
Alternative 6	equivalent to PFRP			

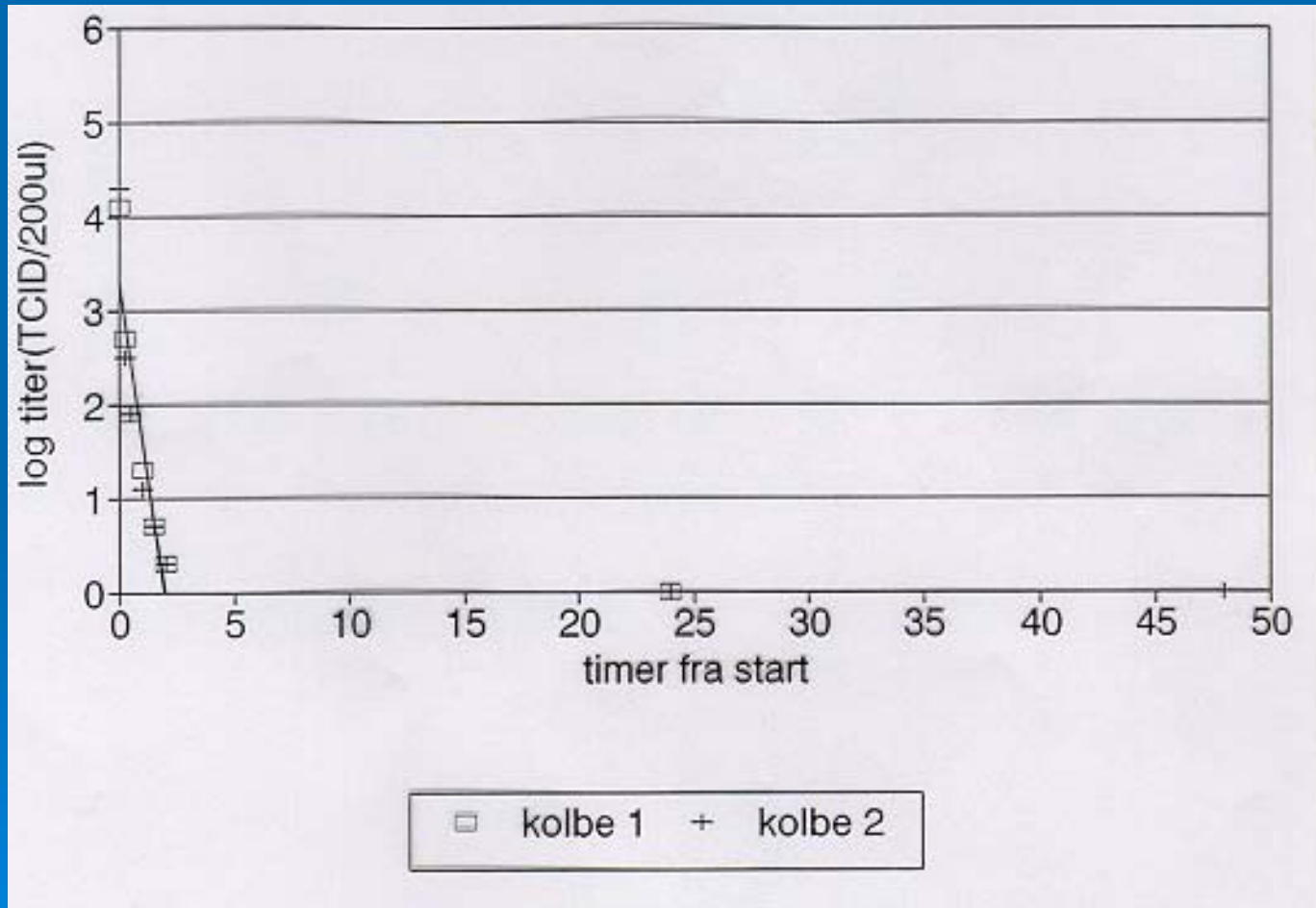
Terminal Island Treatment Plant



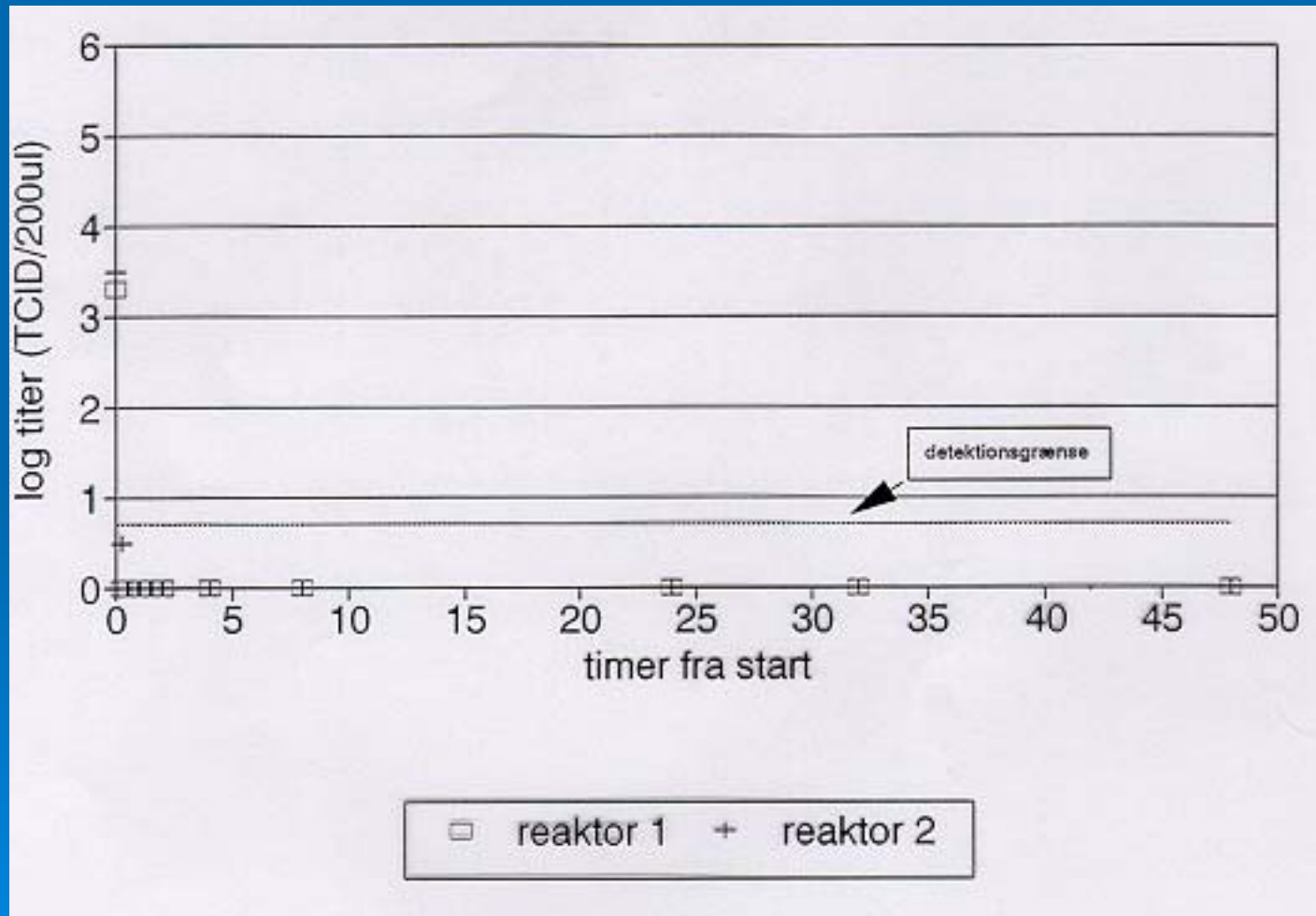
Coliform densities and temperatures



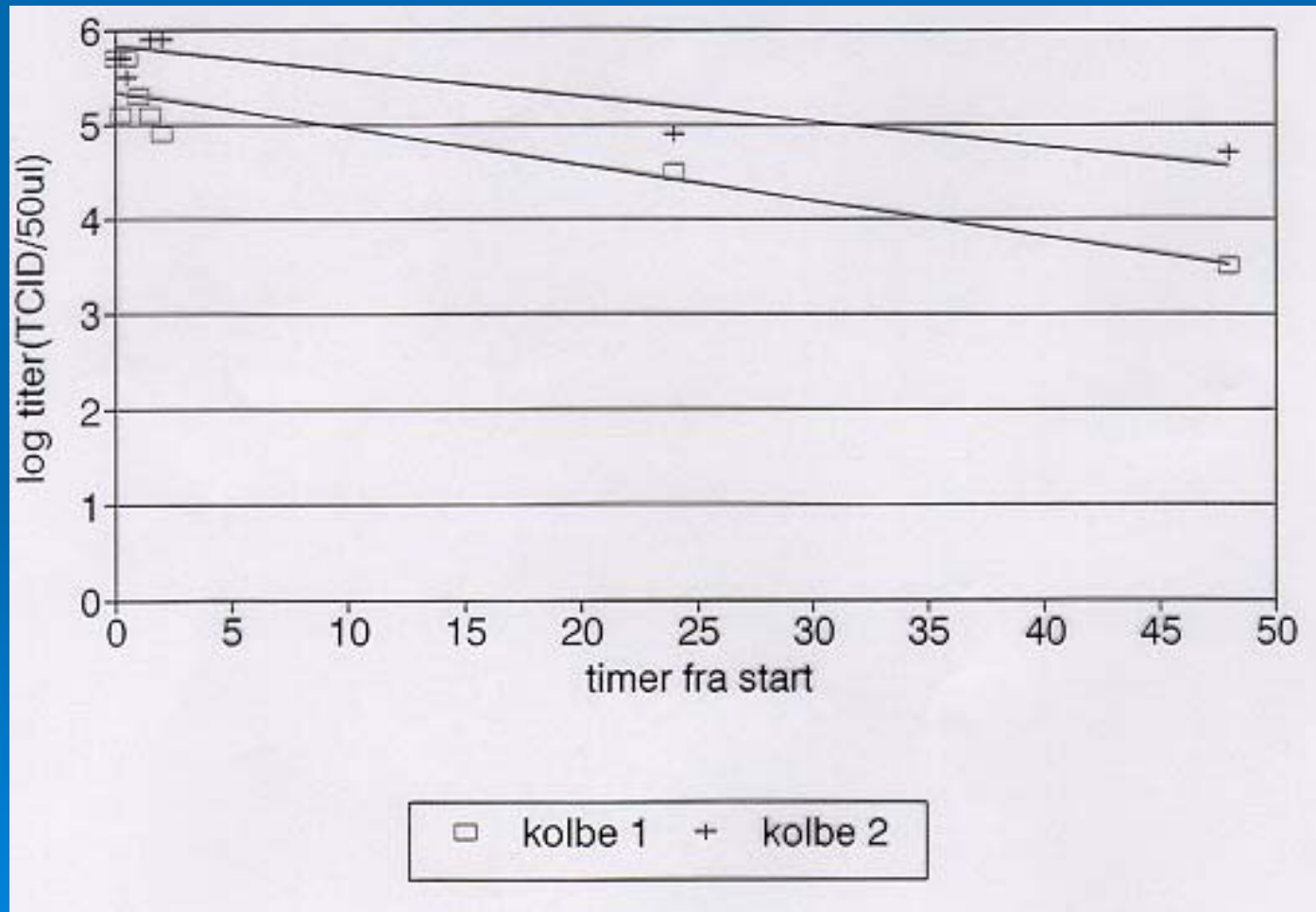
Reduction in Bovine Enterovirus in buffer at 131° F (55° C)



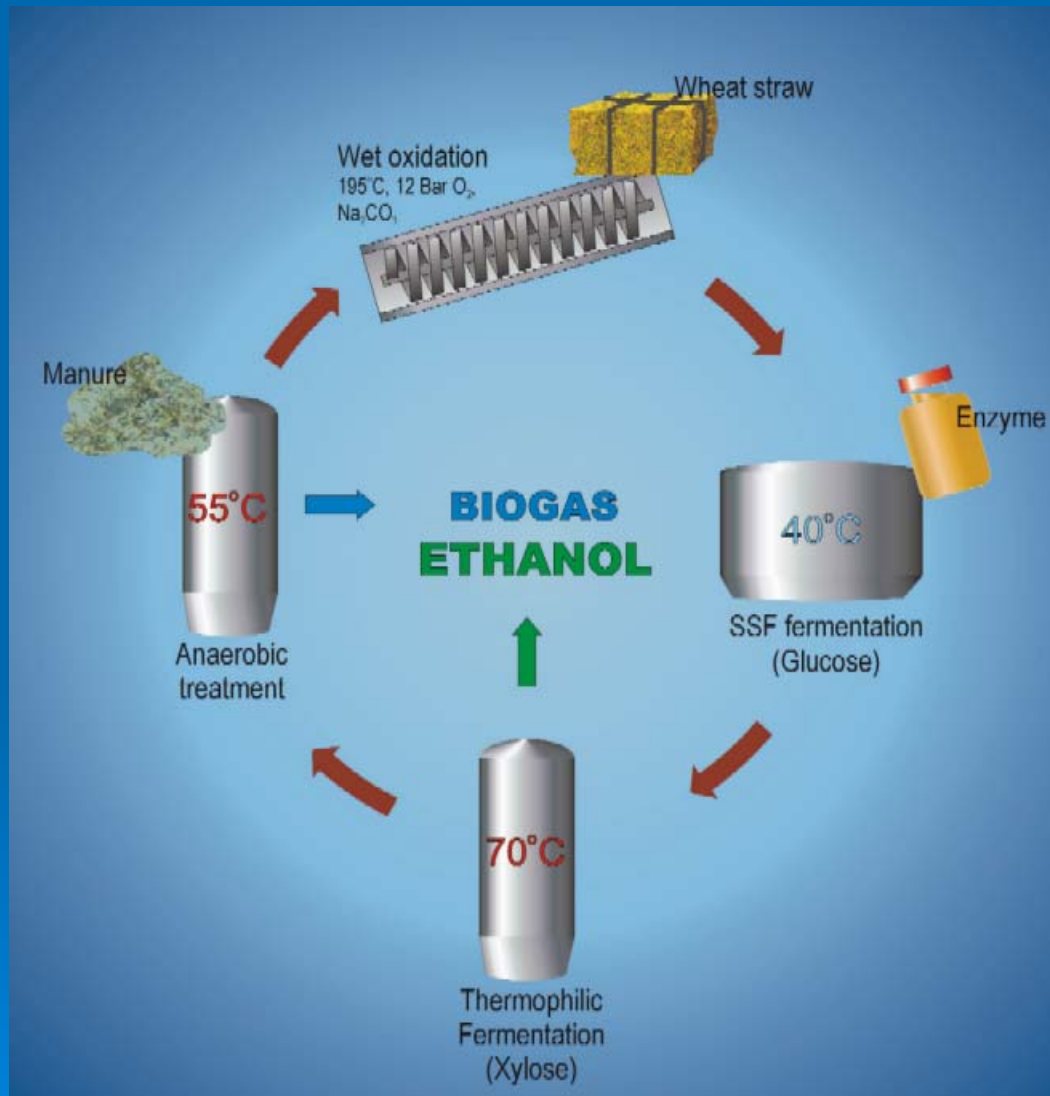
Reduction in Bovine Enterovirus in anaerobic reactors at 131° F (55° C)



Reduction of Parvovirus in buffer at 131° F (55° C)



Bioethanol Concept



Wet Oxidation

In: Wheat Straw

Semi-Solid Fermentation (SSF Fermentation)

In: Enzyme

Xylose Fermentation

Out: Ethanol

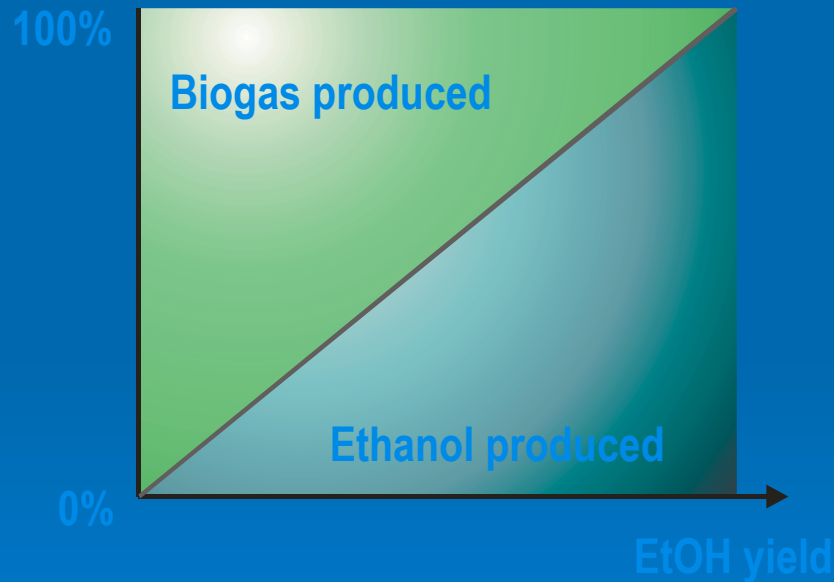
Anaerobic Treatment

In: Manure

Out: Biogas

Optimal Bioconversion

Biomass converted

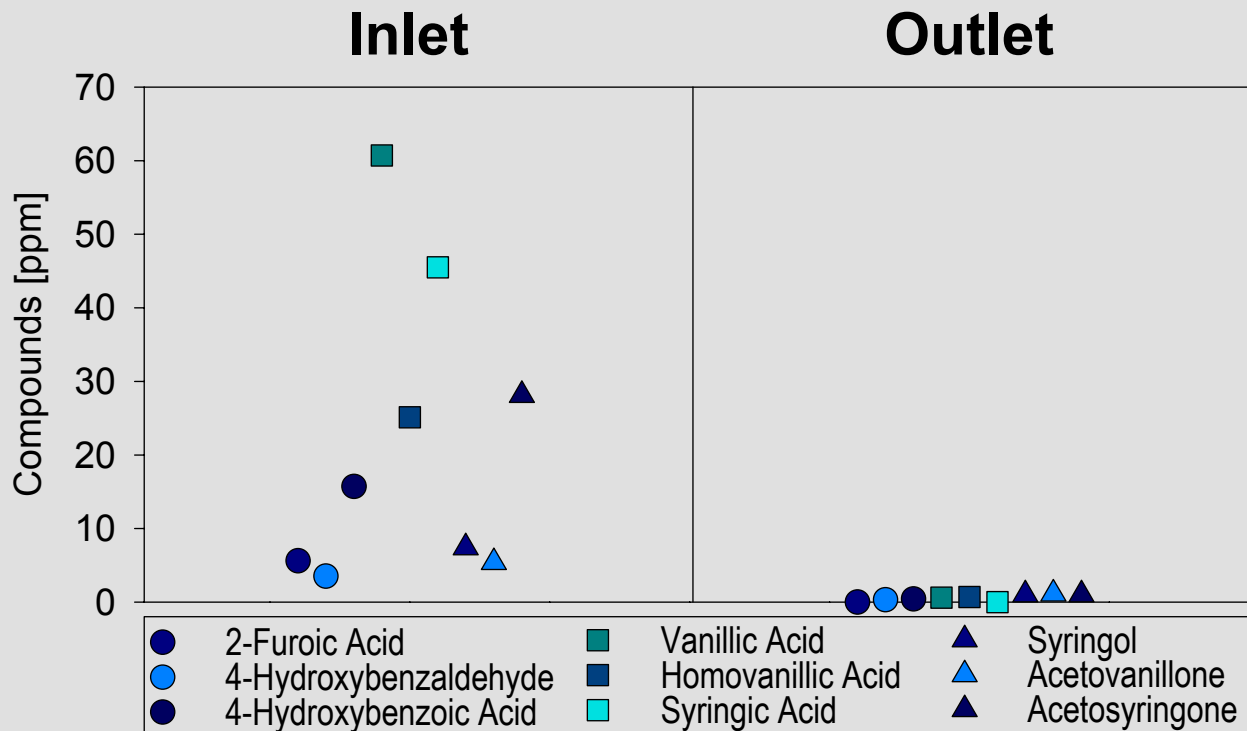


The extra step producing methane ensures optimal utilization of the biomass.

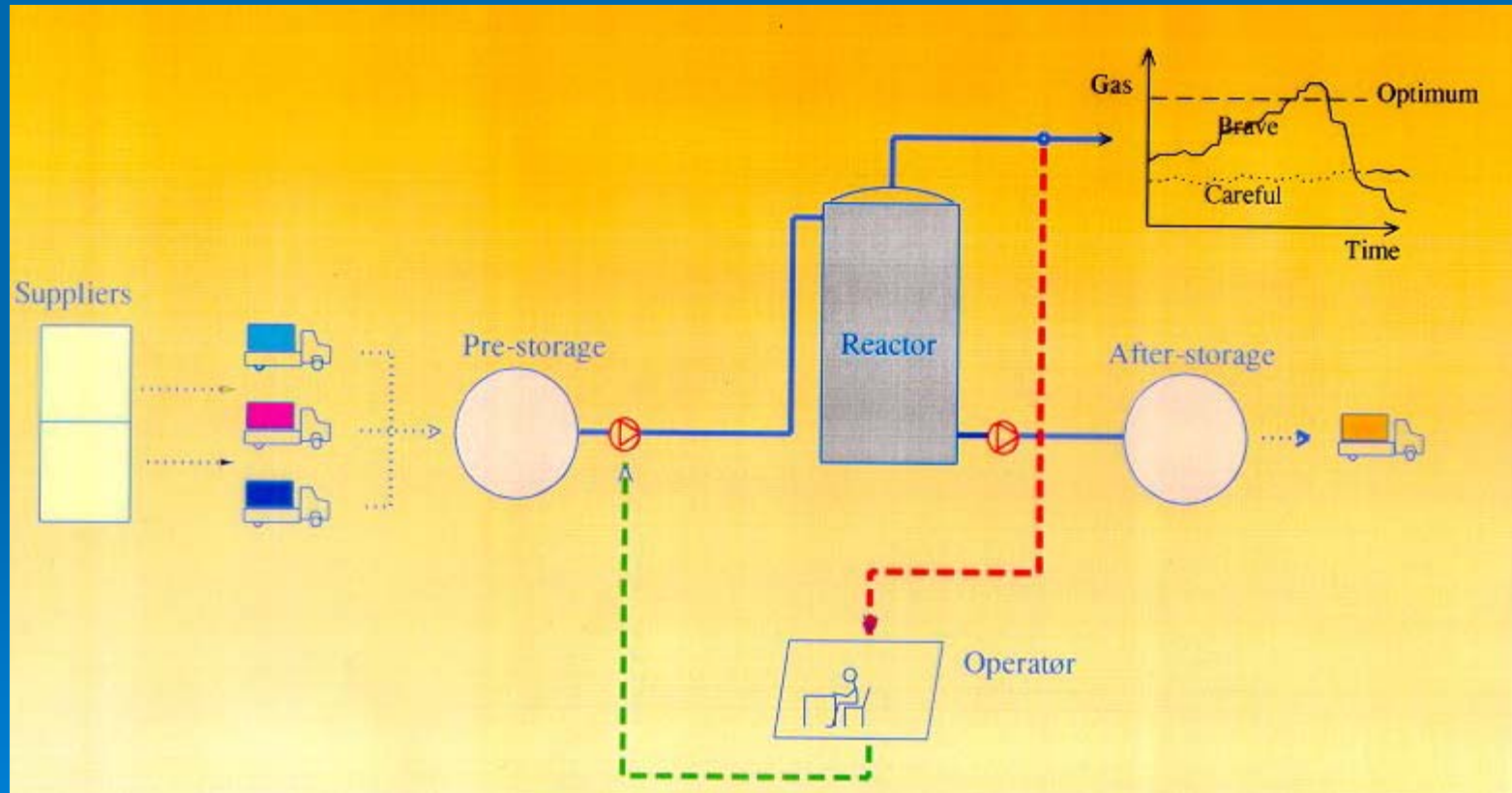
What is not transformed into ethanol can be converted into methane

Anaerobic Treatment

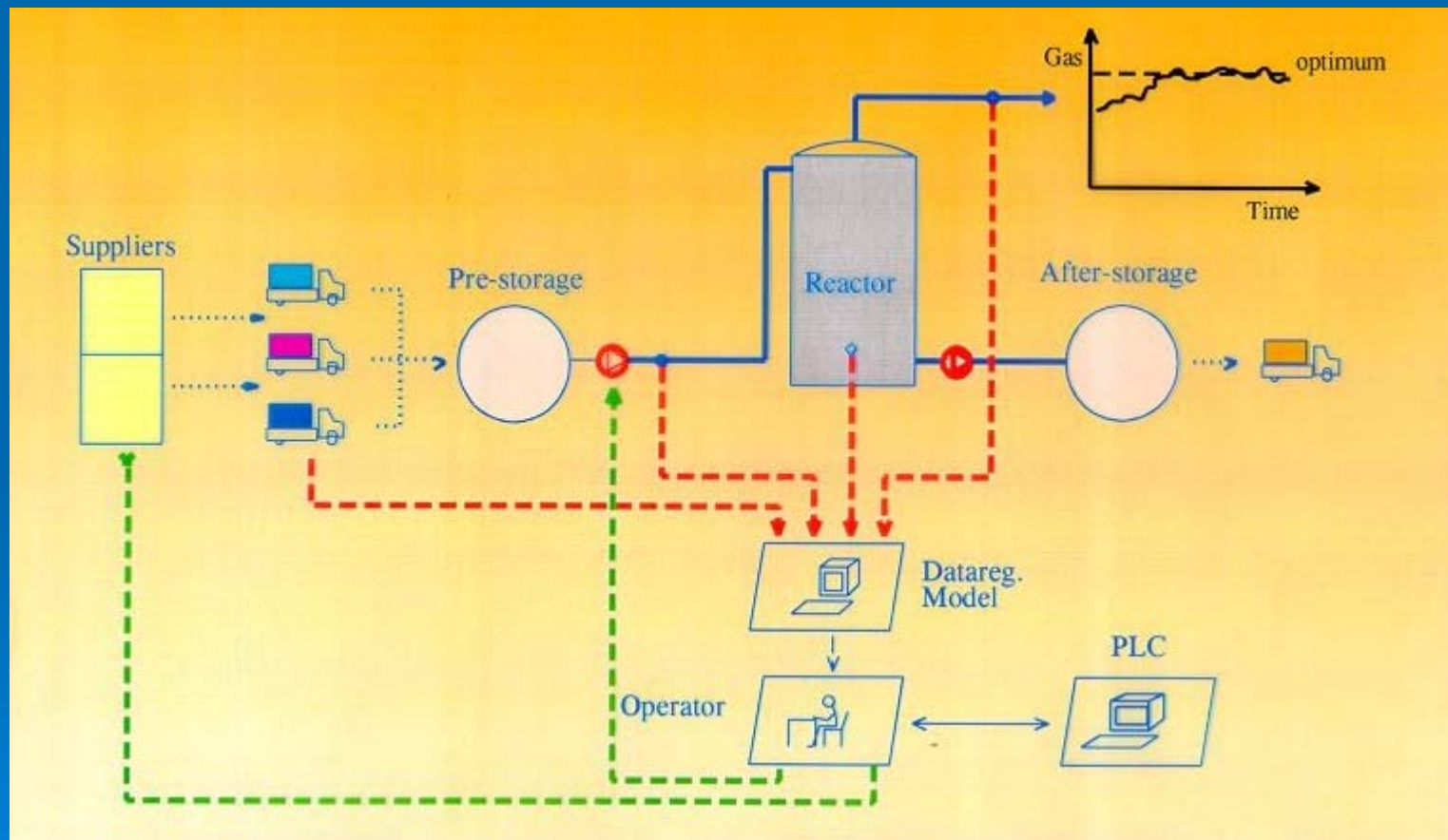
Inhibitor - Removal



Limited control



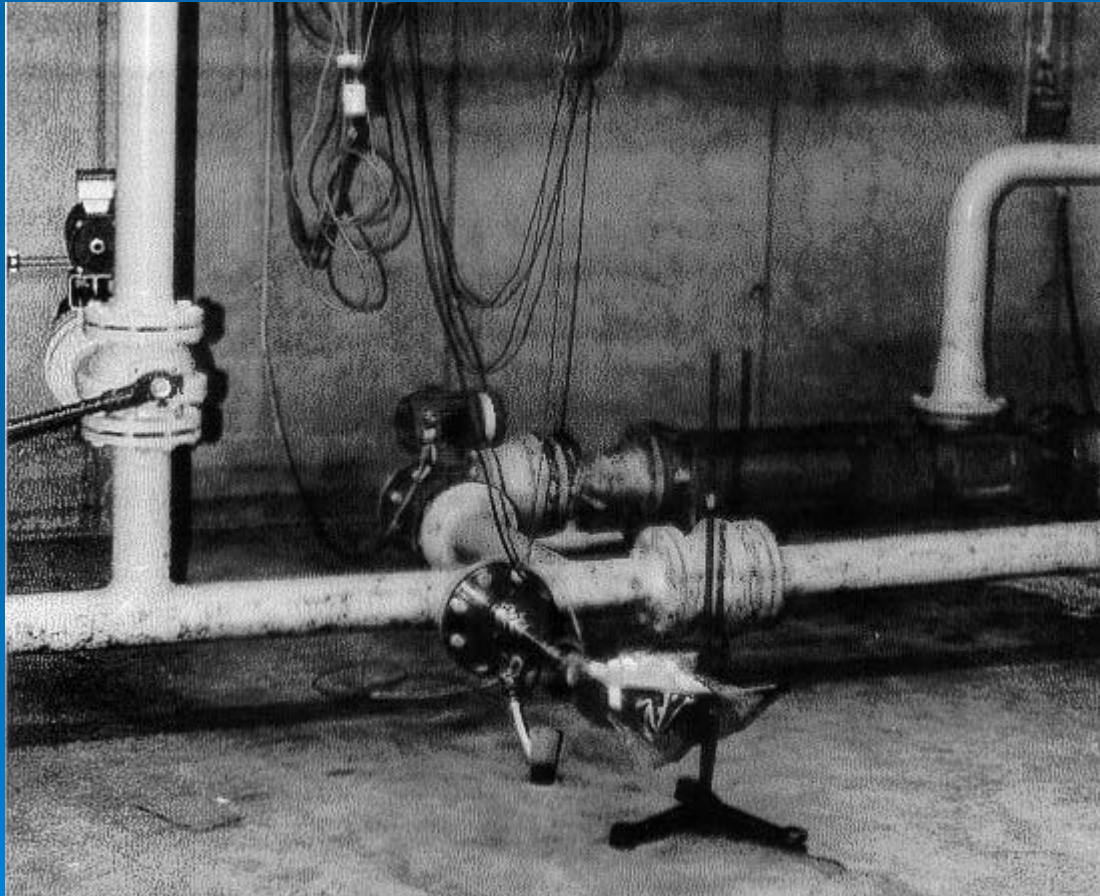
Optimized control



VFA sensor



Filter unit



Conclusion

- The future challenges of AD is related to both gas production and effluent quality
- Mesophilic AD is less efficient than thermophilic AD
- Thermophilic digestion has had a difficult past but the future is bright
- Start-up of thermophilic digesters can be rapid even without seed
- Extreme thermophilic digestion is possible and can ensure much better sanitation of the material
- Co-digestion is a way to obtain a higher gas production and to reuse various organic wastes such as MSW, food processing wastes and industrial waste
- Extreme thermophilic digestion can increase the VS destruction and improve the effluent quality
- On-line, real-time control systems can greatly increase stability and over-all performance of thermophilic AD systems